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Comparison of In Situ Aerosol Data from the ACE-Asia 2001 Experiment

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Abstract

The Asian Pacific Regional Aerosol Characterization Experiment (ACE-Asia) is an international, multidisciplinary project to further knowledge about atmospheric aerosols. ACE-Asia included an intensive field measurement campaign during the spring of 2001 off the coasts of China, Japan and Korea.

The Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies (SIMBIOS) Project participated in the ACE-Asia cruise of the R/V Ronald H. Brown, which departed from Hawaii on 15 March 2001, sailed west to the Sea of Japan, and finished in Yokosuka, Japan on 19 April 2001. The SIMBIOS Project (http://simbios.gsfc.nasa.gov) compares and merges data projects from multiple ocean color missions. As In Situ data are essential for merger and comparison of satellite ocean color measurements, the Project is interested in instrumentation development and data base building.

The SeaWiFS Bio-optical Archive and Storage System (SeaBASS; http://seabass.gsfc.nasa.gov) is the database used and maintained by the SIMBIOS project. ACE-Asia In Situ aerosol data were stored in SeaBASS, so that cruise was an excellent opportunity to compare data from a variety of maritime sun photometers. Several aerosol conditions were experienced. These included low Aerosol Optical Thickness (AOT) maritime conditions near Hawaii and extremely high AOT dust conditions in the Sea of Japan. Concurrent measurements were made with the a Laboratoire d'Optique Atmosphžique (LOA) SIMBAD, a Laboratoire d'Optique Atmosphžique (LOA) SIMBAD-a, two Solar Light, Inc. Microtops II's, and Brookhaven National Laboratory's Fast Rotating Shadowband Radiometer (FRSR). In addition, a Micro Pulse LIDAR (MPL) was deployed that provides vertical aerosol distributions.

Data were processed utilizing new algorithms to screen errors due to improper pointing at the sun, a problem previously recognized for the Microtops II. Comparisons of AOT at 500nm and Angstrom Exponent were made for all the instruments. The hand held, direct solar sun photometers (Microtops II, SIMBAD and SIMBADa) agreed within uncertainties despite differences in calibration technique and human operators. This raises the possibility of creating a uniform, instrument independent, AOT product for ACE-Asia. The FRSR AOT and Angstrom Exponent values were not always within the uncertainties of the hand held sun photometers. This is understandable because of the different methodologies of the two instrument types. However, the FRSR is automated, so it provides a higher temporal resolution and more consistent time series of aerosol condition changes. Finally, In Situ data are compared to SeaWiFS aerosol products.

Experiment

The R/V Ron Brown departed from Hawaii on 16 March 2001 and arrived in Yohosuka, Japan on April 19th. On the way it encountered a variety of atmospheric aerosol conditions, including low optical thickness maritime conditions during the start of the cruise, and high optical thickness, dusty conditions in the latter part of the cruise. A variety of sun photometers were deployed on the R/V Ron Brown, providing an ideal data set for instrument comparison. Table 1 lists the various instruments that were deployed, along with the center wavelengths of the various instrument bands. Figure 1 shows the geographic distribution of the data throughout the entire cruise. -

Figure 1: ACE-Asia Aerosol data

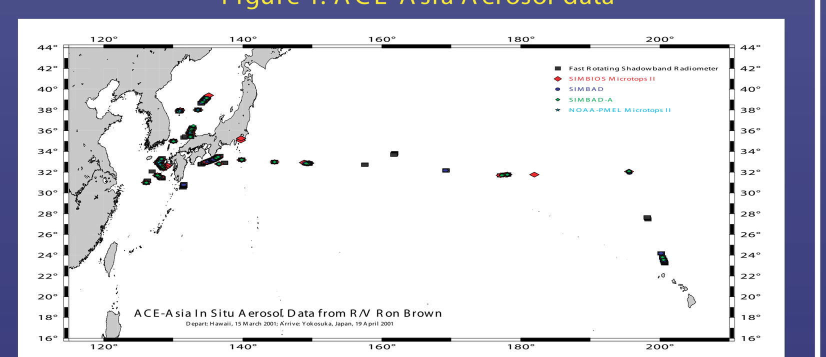


Table 1: ACE-Asia Sun Photometers

Instrument Name	Type	Calibration Technique	Center wavelengths, per band (in nm)												
SIMBAD	Direct Solar	Cross calibration: CIMEL*				443	490			560		670		870	
SIMBAD-A	Direct Solar	Langley calibration	350	380	412	443	490		510	560	620	670	750	870	
Microtops - NOAA-PMEL	Direct Solar	Langley calibration		380		440		500				675		870	
Microtops - SIMBIOS	Direct Solar	Cross calibration: CIMEL*				440		500				675		870	936
Fast Rotating Shadowband	Shadowband	Langley calibration			410			500			615	680		870	940

*SIMBIOS Project sun photometers are calibrated on land by a cross calibration to CIMEL sun photometers maintained by the AERONET Project. The CIMEL sun photometers are calibrated with the Langley method at Mauna Loa.

Figure 2: ACE-Asia Aerosol Optical Thickness

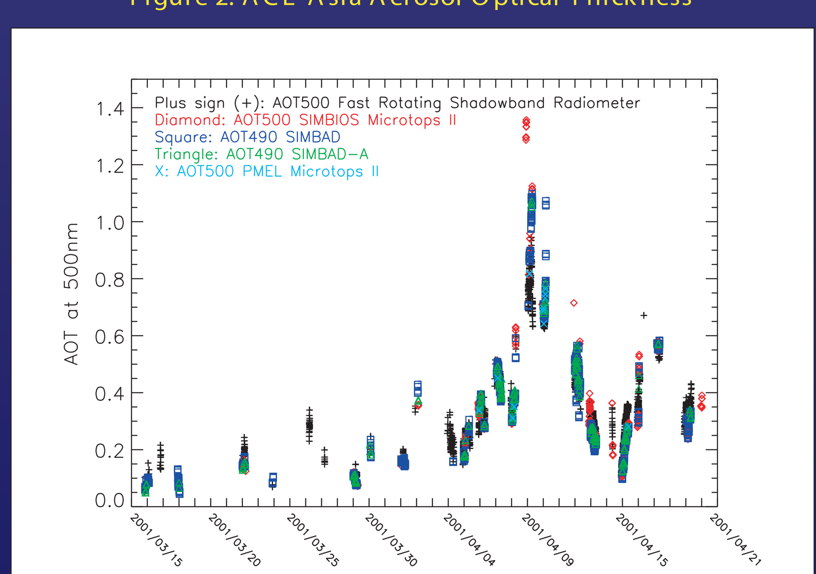
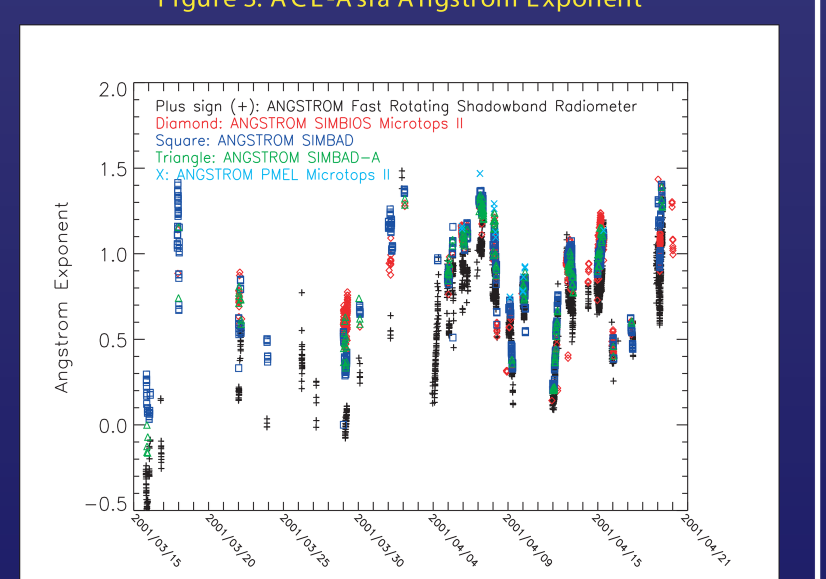


Figure 3: ACE-Asia Angstrom Exponent



Data

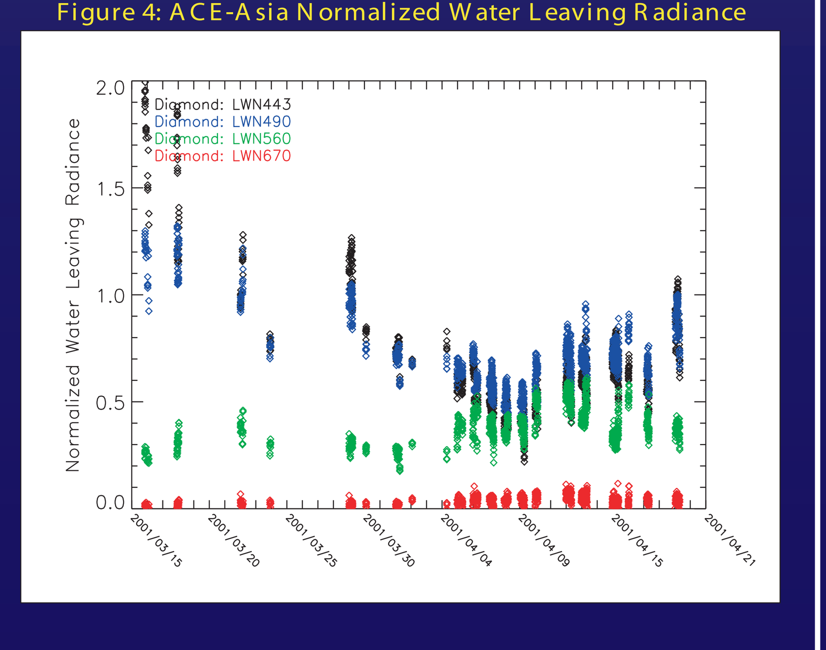
Figures 2, 3 and 4 show the entire AOT, Angstrom and Water Leaving Radiance values measured on the R/V Ron Brown. All three figures show two distinct atmospheric scenarios. The first, from the start of the cruise until about April 4th, exhibits characteristics of open ocean maritime aerosols (Smirnov, et al. 2002), such as AOT at 500nm values around 0.07. Aerosols from the rest of the cruise included dust from the Asian continent, and therefore much higher AOTs.

Although Table 1 shows a variety of available AOT bands, the 500nm (and 490nm, for the SIMBAD and SIMBAD-A) band was chosen for study because it is less vulnerable to temperature effects (due to higher signal values), is common to all instruments, and has been studied previously in the literature. Figure 2 shows the entire AOT data set for all the instruments throughout the course of the cruise. Each instrument's data was processed to remove cloud contaminated and other erroneous data points. (Knobelspiesse, et al. 2002) (Reynolds, et al. 2000)

The Angstrom Exponent, shown in Figure 3, was calculated for each instrument by computing the linear fit to the log AOT values for bands between 412nm and 870nm. The Angstrom exponent is the negative slope of this fit. This method was chosen over the band ratio method to fully utilize the available multiple band data. In the case of the Fast Rotating Shadowband Radiometer, the 410nm and 680nm bands were excluded from the calculation due to known calibration problems.

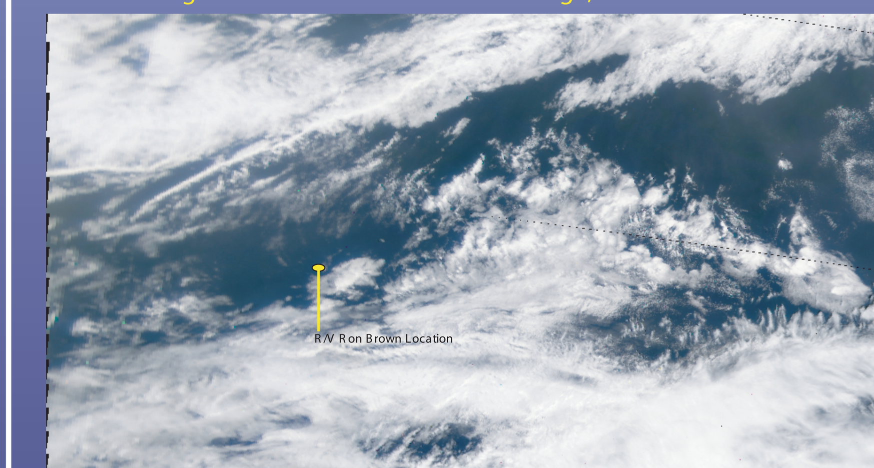
Figure 4 shows the normalized water leaving radiance values, per band, from the SIMBAD instrument during ACE-Asia. These data were available from the SIMBAD instrument because it alternatively measures the solar and water leaving radiances. While the SIMBAD-A also measures water leaving radiance values, the instrument is still in development and those values are not yet available.

Figure 4: ACE-Asia Normalized Water Leaving Radiance



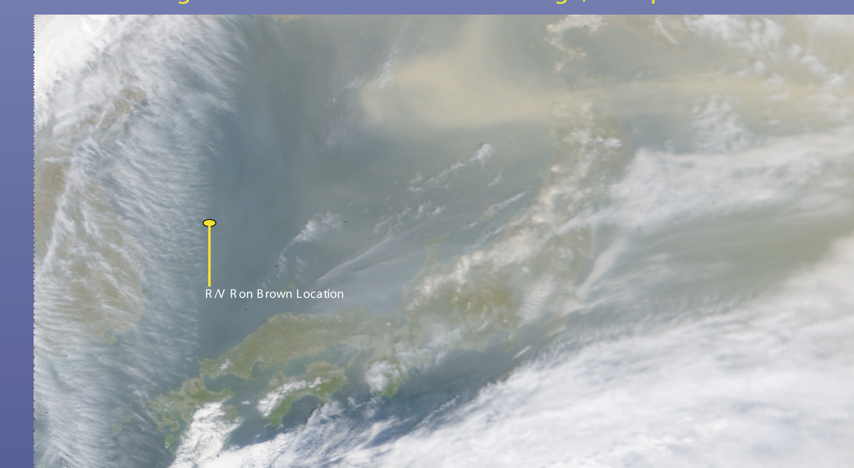
29 March 2001

Figure 5: SeaWiFS Truecolor image, 29 March 2001



10 April 2001

Figure 6: SeaWiFS Truecolor image, 10 April 2001



Two ACE-Asia days were chosen for detailed analysis. The first, 29 March 2001, was chosen as an example of standard deep sea maritime conditions. The other day, 10 April 2001, was chosen because the data are heavily influenced by Asian dust. Figures 5 and 6 show the SeaWiFS truecolor composite images for 29 March 2001 and 10 April 2001, respectively. Figure 5 shows expected conditions for the western Pacific ocean at this time, while Figure 6 shows large dust clouds. The data displayed for 10 April 2001 are heavily influenced by this dust. Even so, the location of the R/V Ron Brown on the 10th April 2001 was not even in the maximum dust location, to the North-East of the ship position.

Figure 7: Aerosol Optical Thickness, 29 March 2001

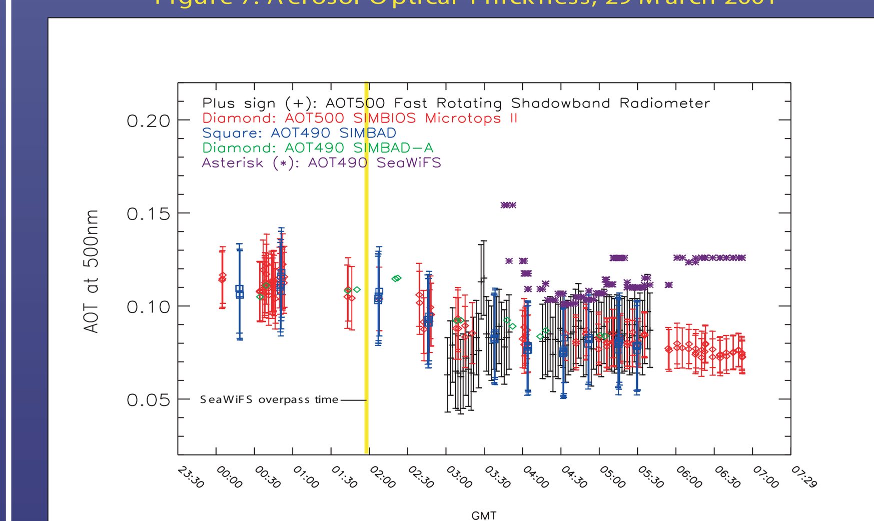
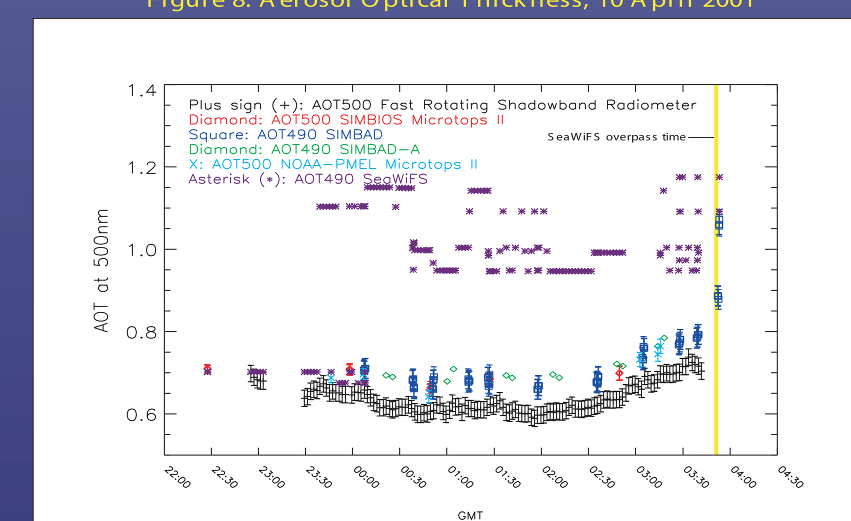


Figure 8: Aerosol Optical Thickness, 10 April 2001



The AOT values from several instruments on board the R/V Ron Brown are shown in Figures 7 and 8. Error bars are shown for data sets where error analysis was available. The SeaWiFS overpass time is shown in yellow. Data points from this SeaWiFS image are also shown, although the comparison with In Situ data is not totally appropriate. The SeaWiFS data points are taken from an instantaneous point in time, and are plotted where In Situ data points were measured at the same location. The SeaWiFS - In Situ comparison is most appropriate at the SeaWiFS overpass time. Figure 7 shows a maritime aerosol situation, with data within the range of 0.06 to 0.12. Data from the three hand held, direct solar sun photometers always agree within uncertainties, while comparisons to the FRSR agree within uncertainties in most situations. SeaWiFS data are outside uncertainties for the other instruments, but provide a general estimate of the AOT. Figure 8 shows a dusty aerosol situation, with AOT values up to an order of magnitude larger than in Figure 7. Hand help sun photometers still agree within uncertainties for this day, while the FRSR underestimates the AOT with respect to the hand held sun photometers by about 0.05 to 0.1. SeaWiFS values for this day are considerably larger than the in situ data. This is partly because the large aerosol reflectivity creates top of the atmosphere radiances that the SeaWiFS atmospheric correction algorithm confuses as clouds. To avoid this problem, cloud masking radiance thresholds were raised so processing would continue in high aerosol locations. To confuse matters further, the SeaWiFS overpass occurred just prior to the arrival of actual clouds, so part of the SeaWiFS signal could be confused with cloud signal. In addition, the SeaWiFS Aerosol models do not include aerosols experienced in the latter half of Ace-Asia.

Figure 9: Angstrom Exponent, 29 March 2001

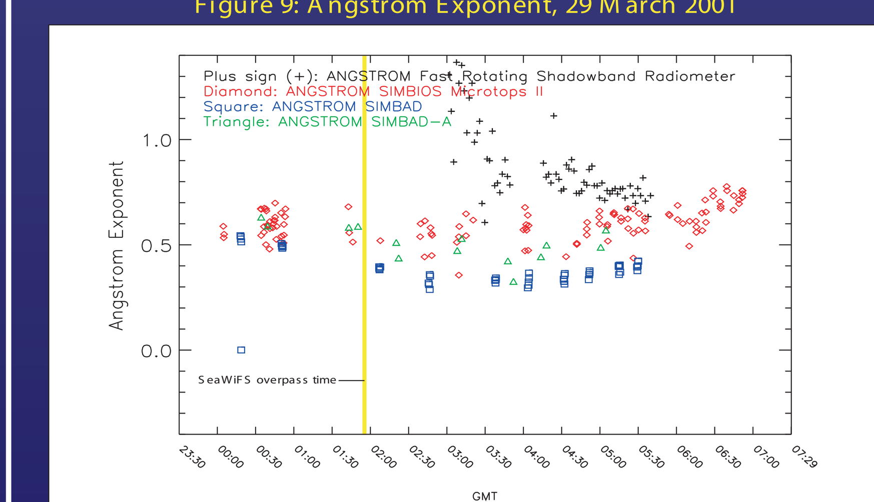
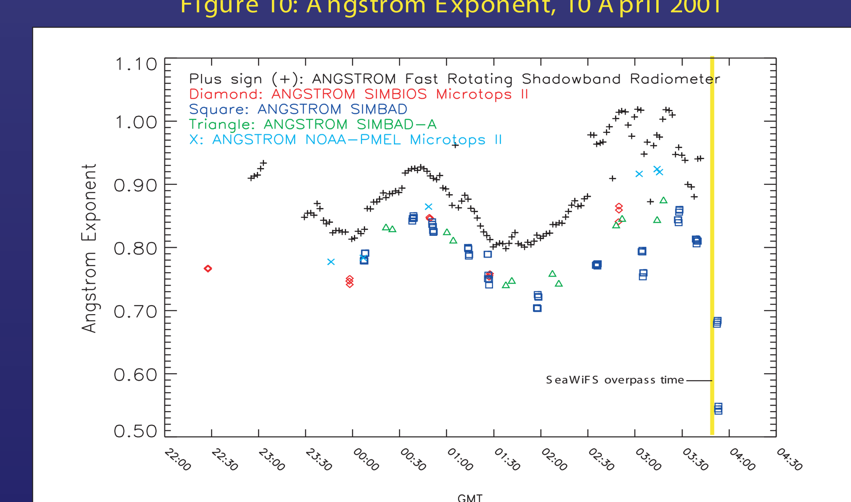


Figure 10: Angstrom Exponent, 10 April 2001



Angstrom Exponent values are shown in Figures 9 and 10. Unlike Figures 7 and 8, the variety of instruments used showed greatest agreement on 10 April 2001. AOT values on that day were much higher, thus increasing the accuracy of the Angstrom Exponent calculation. Like before, the hand held instruments showed greater agreement than when compared individually to the FRSR. On both days, the FRSR overestimated the Angstrom Exponent with respect to other instruments.

Figure 11: LIDAR Normalized Relative Backscatter, 29 March 2001

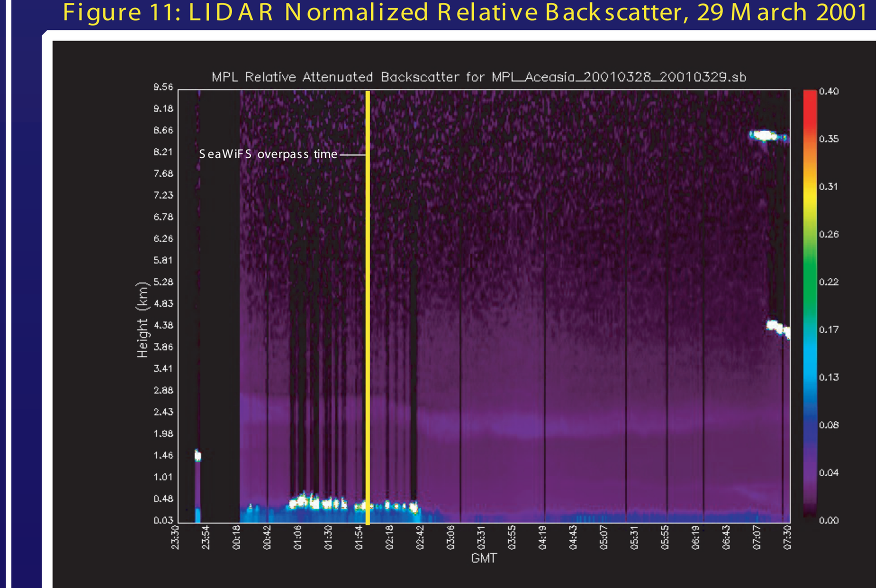
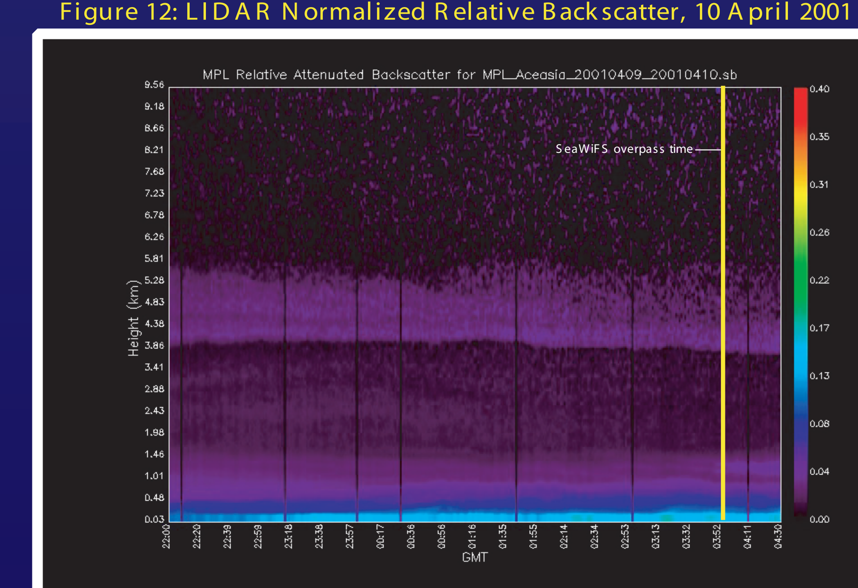


Figure 12: LIDAR Normalized Relative Backscatter, 10 April 2001



Figures 11 and 12 show Normalized Relative Backscatter (NRB) images from the Micro Pulse LIDAR on board the R/V Ron Brown. Height distribution differences between the two days are illustrated, as the dusty day (Figure 12) shows a higher layer of backscatters than the standard maritime day (Figure 11). Height distributions affect comparisons of data from instruments using different measurement geometries. In this case, the standard maritime day (Figure 11) shows better comparison potential, as backscattering aerosols are lower to the ground.

Figure 13: AOT scatter plot comparisons

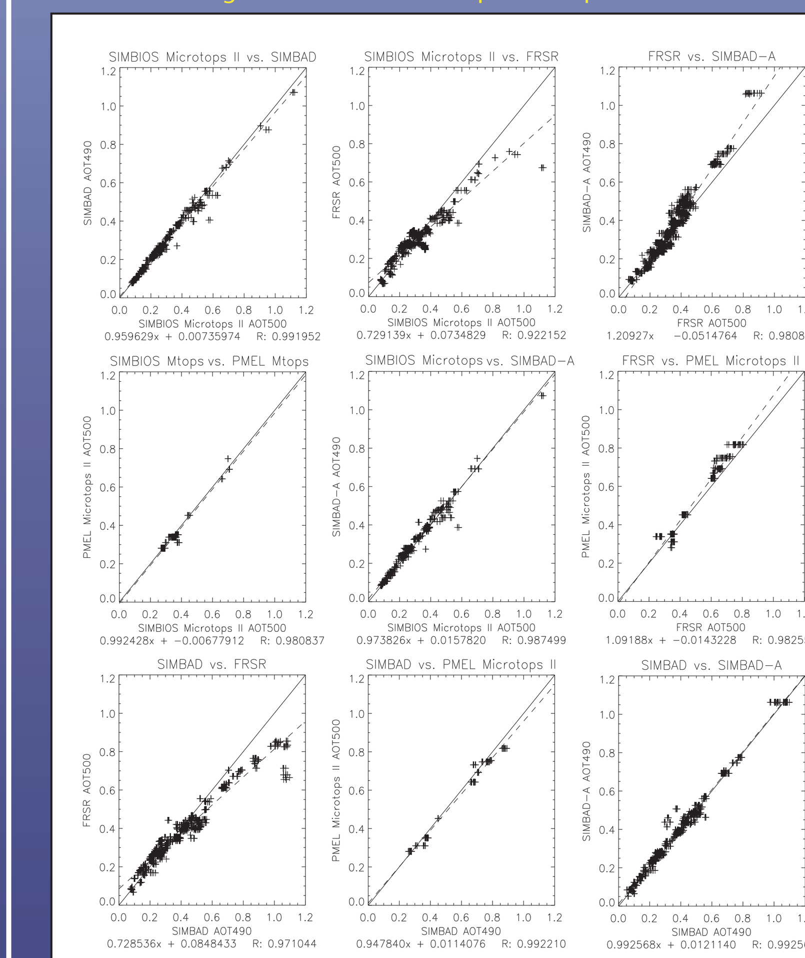


Figure 13 shows scatter plots for AOT at 500nm for various instruments from the entire R/V Ron Brown ACE-Asia cruise. Comparisons were made with data points that were measured within 30 minutes of each other. Linear fits to each plot for hand held instruments has slopes close to one. Comparisons between the FRSR and other sun photometers show that the FRSR underestimates AOT at values above about 0.3, and overestimates AOT at values below 0.3

Figure 14: AOT scatter plot comparisons

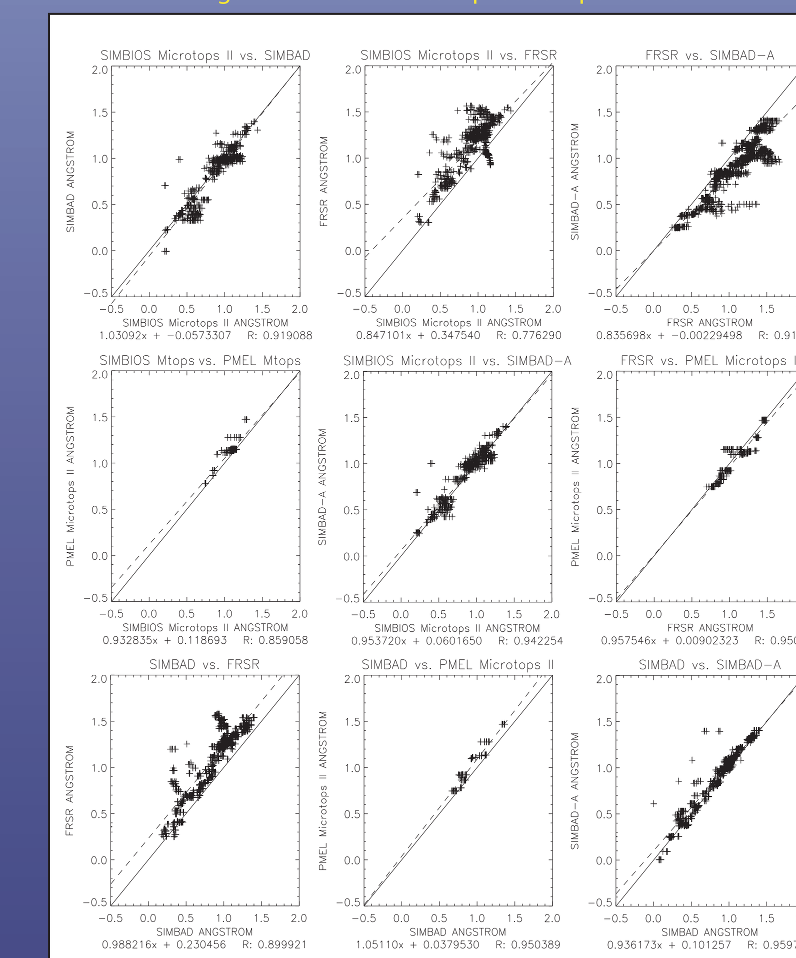


Figure 14 shows scatter plots for Angstrom Exponent for various instruments from the entire R/V Ron Brown ACE-Asia cruise. As expected, scatter is much higher for these comparisons than with AOT comparisons. As in Figure 13, the FRSR shows a bias with respect to other sun photometers. In this case, the FRSR tends to slightly overestimate the Angstrom Exponent.

Figure 15: SeaWiFS AOT at 490nm image, 29 March 2001

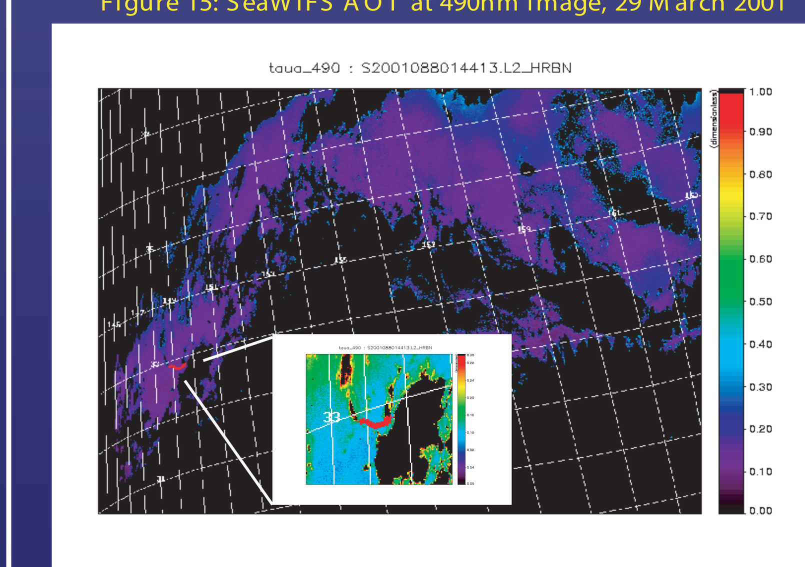


Figure 15 shows the SeaWiFS AOT at 490nm for the low AOT day, 29 March 2001. The R/V Ron Brown's location is shown in red. A zoom of this region with an enhanced color mapping is shown in the insert.

Figure 16: SeaWiFS AOT at 490nm image, 10 April 2001

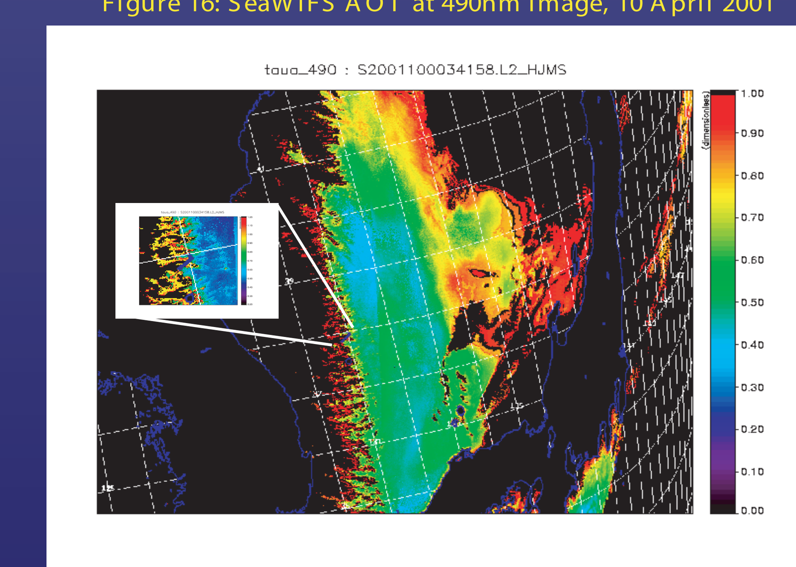


Figure 16 shows the SeaWiFS AOT at 490nm for the high AOT, dusty day, 10 April 2001. The R/V Ron Brown's location is shown in blue. A zoom of this region with an enhanced color mapping is shown in the insert. The data were processed using several modifications to the standard SeaWiFS atmospheric correction. These modifications were intended to account for the high aerosol reflectance.

Conclusion

Data from three types of aerosol optical measurement instruments are shown here. Optical thickness and Angstrom exponent data from In Situ, hand held, direct solar sun photometers, such as the Microtops II, SIMBAD and SIMBAD-A, agree within uncertainties for the entire cruise, despite differences in calibration technique and measurement personnel. This leads to the conclusion that these instruments provide consistent and robust measurements. However, they require a human operator, and thus are most expensive to deploy. The FRSR provides data that is not as reliable as hand held sun photometers, but has a higher frequency of measurement due to automation. As calibration techniques and other unique engineering issues for the FRSR are refined, the instrument could become more reliable. Differences between the FRSR and the hand held instruments are greatest for extremely high and extremely low optical thicknesses. This implies that in situ measurements at high optical thickness events, like the Asian dust during ACE-Asia, should be combined with more accurate hand held sun photometers. Quantitative satellite measurements of aerosol optical properties during high optical thickness events remains elusive, as high aerosol reflectances confuse cloud masking routines and are not considered in the atmospheric correction aerosol models. Satellite images, however, can be extremely valuable tools for qualitative analysis over a large area that cannot be sampled on the ground.

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